A NEW METHOD OF TRANSITING STARS.

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The method of observing transits of stars, here to be described in a preliminary and general manner, consists in driving the micrometer screw and hence micrometer thread of a transit instrument by means of an electric motor at the uniform speed pertaining to any given declination, at the same time that the observer by secondary adjustment secures and maintains accurate bisection of the star, while given positions of the screw and hence thread are automatically recorded on a chronograph.

It is now more than four years since the writer described the method to his associates interested in astronomical observation. In the autumn of 1899 this plan of electrically driving the transit thread was also mentioned to Professors Wadsworth and Morley and at some length discussed with the latter. Working drawings of the special instrument which at present gives concrete expression to the method were completed in September, 1900. The "electrical transiter," or more simply "transiter," as for brevity the new device has been named, was mounted on the small meridian circle of the Philadelphia Observatory in February, 1901, and there subjected to many tests and improvements since. The demands on the writer's time have, however, not permitted that singleness of devotion which the transiter and its interesting method should receive, and it does not, therefore, seem desirable any longer to withhold a preliminary communication on the subject.

The fundamental idea of moving a transit micrometer wire by means of clockwork synchronously with the star's motion was proposed in 1865 by Braun.[1] But to Repsold is due the persistent pursuit of the idea that personal equation can be banished from transit observations by mechanical methods. And although his practical solutions of the problem have hardly proved adequate, they have stimulated and permitted serious efforts on the part of observers.

The first suggestion of Repsold,[2] made in 1888, was to mount the

[1] Dr. Carl Braun, *Das Passagen-Mikrometer*, Leipzig, 1865.

[2] F. Repsold, "Durchgangs-Instrument mit Uhrbewegung," *Astron. Nach.*, 2828.

base of the transit instrument on a polar axis and within a limited range drive the instrument to the diurnal motion by means of clockwork, and in some undescribed manner keep the star bisected so as to determine the meridian passage through electrical signals automatically made. The plan admirably met the chief difficulty of the varying rate of motion due to difference of declination, but was abandoned on account of the great mass to be moved.

It has to the writer, however, seemed likely that by applying a powerful electric motor of strictly constant speed, and by using a second electric motor with regulable speed for driving one element of a differential gear which engages the shaft driven by the main motor, or by several other electrical devices not requiring mention, an equatorially mounted transit instrument can be driven to stellar bisection and readily kept so adjusted.

A second plan, "Neuer Vorschlag zur Vermeidung des persönlichen Zeit-Fehlers bei Durchgangs-Beobachtungen," was proposed by Repsold[1] in 1889 and tested by Becker[2] in 1891 with moderately favorable result A new form of micrometer, made for the Madison Observatory by Repsold,[3] was described in 1896, and with the general plan of its construction the writer became acquainted in the autumn of 1897. This specially designed and rather complicated micrometer requires that star bisection shall be maintained by twirling the micrometer shaft alternately with each hand of the observer. While this twirling is proceeding the ten electrical contacts of a drum mounted on the micrometer screw determine as many records on the chronograph. This Repsold method, while not lacking in ingenuity, seemed to the writer to labor under the following defects: An alternating twirling motion of the micrometer, even when communicated with the greatest adroitness, is not approximately a uniform motion. The observer is attached to the instrument by both hands, and is incessantly committed to the most painful attention. Good results could hardly be secured without the most prolonged and painstaking practice. Through his special habit of twirling each observer must have a new form of

[1] F. Repsold, *Astron. Nach.*, 2940, 1889, September.

[2] Prof. E. Becker, "Ueber einige Versuche von Durchgangs Beobachtungen nach dem neuen Repsold'schen Verfahren," *Astron. Nach.*, 3036, 1891, März.

[3] "Neue Mikrometer von A. Repsold u. Sohne," *Astron. Nach.*, 3377, 1896, Juli.

personal equation. Even the averaging secured by the great number of electrical contacts does not certainly eliminate the peculiarities of a given habit of twirling. At any rate the great number of signals to be read from the chronographic sheet constitutes a very serious infliction on time and patience. Finally, the Repsold method does not, during any given star transit, offer a ready and direct means of comparison with the ordinary methods of observation.

The difficulties experienced in acquiring reliable observing habits with the Repsold transit micrometer are evident from the reports of Becker,[1] Kowalski,[2] and Flint.[3] The latter is, it seems, the only American observer who has tried the Repsold device to any extent, and he says that "after considerable practice" he obtained the same probable error by the method for "a signal under good conditions as for a single thread when observing with a fixed reticule and chronograph."

And yet it is not surprising that among European observers engaged in longitude work, the Repsold method should after prolonged discipline yield excellent results. Albrecht,[4] in an extended paper on its application to longitude work, points with enthusiasm to the superior results obtained. He considers the former indifferent results to be due to lack of practice and insists that the highest effectiveness, by this method, is attained only after a long season of active experience. "Man erlangt das Maximum der Leistungsfähigkeit doch auch bei dieser Methode erst nach langer Uebungszeit."

These experiences of practiced observers, while pointing to the value of the plan of micrometer thread motion in eliminating personal equation and its variations, confirm the anticipations of the writer as to the inherent defects of the Repsold method. It is therefore interesting to note that experiments for relieving some of the imperfections of the method have been going on at the Konis-

[1] *Loc cit.*

[2] *Ueber das neue selbstregistrirende Mikrometer von Repsold*, Petersburg, 1897.

[3] Albert S. Flint, "The Repsold Micrometer of the Washburn Observatory," *Astron. Jour.*, No. 470, 1899, September.

[4] Prof. Th. Albrecht, "Die Beobachtungsmethode mittelst des Repsold'schen Registrirmikrometers in ihrer Anwendung auf Längenbestimmungen," *Astron. Nach.*, 3699, 1901, März.

berg Observatory, where its Director, H. Struve,[1] has successfully applied clockwork directly to the Repsold micrometer, and thus unquestionably improved its usefulness. With this work the writer became acquainted only after his own plan had been consummated and the resulting instrument constructed and mounted for use. Dr. Cohn,[2] of the same Observatory, has recently published an extended investigation which shows marked advances in accuracy over the usual methods of observing. Struve's method has, however, thus far involved the unsymmetrical placing of the weight of the apparatus and, while itself possessing serious mechanical limitations, does not avoid certain peculiarities and limitations of the Repsold micrometer. The necessity therefore still exists for a method that shall be flexible in adaptation and use, and not impose unreasonable conditions on the observer.

The conditions to be attained in an effective method were early formulated by the writer substantially as follows:

The ordinary micrometer of a transit instrument shall be used, and its movable wire driven electrically at approximately uniform speed. The rate of driving shall, as required, vary with the declination. The direction of motion shall be instantly reversible. The wire shall be promptly readily started on its course when bisection of the star occurs. While in motion the wire shall be easily regulable for bisection of the star. The automatic chronographic record shall be made at whole turns or at fractions of a turn of the screw as desired.

In practically studying the electrical method of determining and controlling the motion of the thread of a transit micrometer, it has been found that there are three principal plans of adaptation available:

I. A small electric motor may be placed on or near the head of the transit instrument, with its axis parallel to that of the instrument. The varying rate of motion required for change in declination may then be secured by regulating the field of the motor and, if necessary, also that of a small dynamo supplying the current. The main difficulties in this plan are, the wide range of

[1] H. Struve, "Ueber die Verbindung eines Uhrwerks mit dem unpersönlichen Mikrometer von Repsold," *Astron. Nach.*, 3719, 1901, März.

[2] Dr. Fritz Cohn, "Ergebnisse von Beobachtungen am Repsold'schen Registrirmikrometer bei Anwendung eines Uhrwerks," *Astron. Nach.*, 3766–67, 1901, November.

speed regulation required and the interference due to inertia at starting.

II. Equatorial speed that is absolutely constant but slightly regulable may be given the motor, similarly placed, and the differing rate of motion proper to each declination determined by mechanical gearing, consisting principally of two friction disks placed at right angles to each other, or by some other mechanical equivalent. Both of these plans require special care in the construction and mounting of the motor, so as to obviate the communication of injurious vibration to the transit instrument.

III. It may in some instances be desirable to place the electric motor on a separate support near the base of the instrument, and then by means of a light steel shaft entering the axis of the transit finally communicate the required motion to the micrometer screw. All the motions and controls peculiar to either of the other plans may be secured to this form of transiter, excepting that the micrometer cannot at all be driven during the time necessary for reversal of the transit instrument. This limitation would in some instances be rather annoying, if not destructive of facilities the method should furnish.

It is also quite feasible to place certain elements of the transiter on a separate support and communicate the motion to a small slow-speed alternating current-motor placed on the head of the transit instrument and connected with the micrometer, and so obviate practically all the mechanical and electrical difficulties. Experiments in this direction are in progress.

In the attempt made to actualize the electrical method of driving the transit micrometer contending obstacles and facilities led, for a first trial, to the selection of the second plan mentioned, namely, that of gearing from a small motor of fixed speed placed near the head of the instrument. In reaching this conclusion the writer was greatly assisted by his friend and former student, Dr. H. G. Geissinger, who, immediately the method of the electrical transiter and the conditions it imposed had been described, became enamored of the delicate mechanical and electrical problem. Detail drawings of a transiter of this type were prepared under the writer's direction by Dr. Geissinger, and he has introduced several ingenious devices which admirably meet the conditions set. The special aim of the writer is to construct a form of transiter that may, without serious modification, be attached to any transit instrument. It should not involve a special form of micrometer nor in any way vitiate the in-

strument for its usual work however accurate. Excepting in the unnecessary weight of the parts and general coarseness of the mechanism, the transiter as now constructed fairly meets all the demands originally set and besides introduces some new conveniences. Although it is not the intention at present to give a detailed description of the transiter, it may be allowable briefly to mention several of its advantages:

Regulation of the bisection of a star is easy and definite. A record is made but once for each revolution of the micrometer, and records will be increased in frequency only as special work demands. A predetermined schedule of recording can be determined for any given run of the micrometer. Back lash of the screw on reversal of motion may be completely eliminated by the adjustment of the electrical contacts. The whole transiter may be balanced symmetrically on the instrument, and thus changes in the instrumental constants avoided. Instantaneous reversal of the motion of the micrometer permits of many conveniences as to method of work. In determinations of time and longitude the tendency has of late been to reverse the transit instrument during the passage of each star, and thus to eliminate a series of errors and facilitate reductions. The transiter by its ability to reverse motion instantly, and even automatically, lends itself readily to this method of work.

From the beginning of 1901, when it was completed, until the present the transiter has been the subject of many tests and of some improvements, and for a year or more it is hoped it may be destined to progressive change. It is now mounted on the four-inch meridian circle, for which it is expected a suitable place may be found at the Suburban Photographic Station of the Observatory, when this Station shall have been definitely located, but only after the completion of the present series of experiments with the transiter, and the determination of the latitude and longitude of the City Station of the Observatory.

Personal equation in all its variations remains a much more serious factor than many painstaking astronomers, who have not sufficiently practiced their accuracy even against a simple personal equation machine, are willing to admit. It is then gratifying to find that Professor Langley[1] has recently been willing to propose

[1] Prof. S. P. Langley presided at the meeting, and had at a recent meeting of the American Astronomical and Astrophysical Society described his new and very ingenious method of obviating personal equation in any time observation.

an entirely novel and highly suggestive method for its elimination in many classes of observation. And it may therefore be permissible, in this presence, to draw attention to the fact that the method of the electrical transiter permits for the first time the determination of the absolute personal equation at any and every desired star transit, and on the star itself. While reserving a complete discussion of this subject for a future occasion, it should be stated that several plans offer themselves to this end in the transiter. To mention but one: The usual wires are undisturbed, and the transiter can be adjusted so as to cut itself in and out automatically at certain parts of the run and only there receive the attention of the observer for star-bisection. At other portions of the run the usual method of chronographic signals, or even of the eye and ear method may be employed, and so, on reduction to the middle, be compared with the transiter's automatic signals. Personal equation may thus be studied with facility on the stars themselves and its variability traced through a simple observation or a series of observations, and whatever is sufficiently stable expressed as a function either of the stellar declination or of stellar magnitude or even of the physical condition of the observer.

It seems rather likely that finally all such study of the personal equation, when it shall have clearly demonstrated the unreliable character of the usual methods of transit observation and the adequate accuracy of the newer method, will be relegated to the Psychological Laboratory. Certain it is that the banishment of reaction time from transit observations and the reduction of this class of errors to those of bisection, either of a star image by a thread or of a thread interval by a star, means an epoch in observational astronomy whose actual realization by suitable devices is a worthy challenge to our best efforts.

With an automatic transiter allowing easy and accurate bisections, a chronograph recording with the utmost accuracy, and a clock of the best mechanism kept under constant pressure and temperature, a new field for accurate work in longitude determination and in the evaluation of stellar position and stellar parallax would be opened to the activity of the astronomer.

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